

**Before the  
Federal Communications Commission  
Washington, D.C. 20554**

In the Matter of	)	
Amendment of the Commission's Rules with	)	GN Docket No. 12-354
Regard to Commercial Operations in the 3550-	)	
3650 MHz Band	)	

**COMMENTS OF INTERDIGITAL, INC.**

InterDigital, Inc. ("InterDigital") hereby submits its comments in the above-captioned docket in response to the Commission's Notice of Proposed Rulemaking and Order regarding commercial operations in the 3550 – 3650 MHz band.

InterDigital is an industry leader in exploring and developing dynamic spectrum use technologies. Since its founding in 1972, the company has been a wireless pioneer that has designed and developed a wide range of technologies used in digital cellular and wireless products and networks, including 2G, 3G, 4G and IEEE 802-related products and networks. The company actively participates in and contributes to the standards bodies that drive the design and function of each generation of wireless technologies. These bodies include IETF, ETSI, 3GPP, SAE, and IEEE 802 among others.

Some of InterDigital's recent contributions to the worldwide standards have been in areas involving multi-carrier technology, heterogeneous deployments, interference management, dynamic spectrum management, small cell support, relays, machine-type communications, security and video over wireless.

Inter Digital is motivated by its commitment to wireless innovation and believes in the strong potential of spectrum sharing technology to meet unprecedented spectrum demand. InterDigital's Dynamic Spectrum Management (DSM) solutions exploit and aggregate the capacity of underutilized bands to dynamically add more capacity to commercial LTE and Wi-Fi® systems, dramatically supplementing bandwidth. Our Wi-Fi (DSM-Wi-Fi) and LTE (DSM-LTE) solutions are being developed for standards-based interoperability to enable scalable and cost-effective solutions. InterDigital is working actively to lead initiatives within key standards organizations such as ETSI, 3GPP, IETF and 802.11 to foster adoption of spectrum sharing capabilities, and is motivated to work across the ecosystem to drive market adoption of shared spectrum in 3.5 GHz.

## **Introduction**

We agree with the Commission that the demand for wireless broadband capacity is growing much faster than the availability of new spectrum and that the future wireless traffic demands also require new wireless network architectures and new approaches to spectrum management. We believe that the development of new technology that enables spectrum to be shared in a dynamic and flexible manner can significantly increase the efficiency of the overall spectrum use.

In our view, developing regulations and technology for the successful sharing of the 3.5 GHz band, requires that: 1) the Incumbent is protected from harmful interference at all times, 2) Availability and reliability of access to the band for commercial use is high, 3) Technology is developed with economies of scale in mind, and 4) Spectrum usage is maximized. Economies of scale can be best achieved by allowing such use which truly benefits from access to additional

spectrum, has a wide user base and utilizes widely deployed technologies such as LTE and Wi-Fi. Furthermore, utilization of mechanisms that provide economic incentives for the incumbents can be an important factor in ensuring a successful deployment of the new technology. In addition to increasing the motivation for the incumbent to make their unused portions of spectrum available for shared use, such mechanisms may generate revenue and cover the operational costs of the new technical entities that manage the spectrum dynamically and automatically.

In these comments, InterDigital addresses the following aspects: (i) the use of small cell technology to facilitate sharing and to reduce the exclusion zones proposed in NTIA's Fast Track Report [1], (ii) techniques to mitigate radar interference, (iii) mitigation techniques to reduce the size of Incumbent Use Zones around existing FSS earth stations, (iv) Priority Access tier systems and technologies, (v) technologies to enable efficient GAA use of the 3.5 GHz band, (vi) use of license-by-rule for Priority Access and General Authorized Access tier users, and (vii) SAS to manage the use of the Citizen's Broadband Service, including the potential use of an economic incentive mechanism for the incumbents, as well as technologies to enable the safe and legally authorized use of the Service.

## **I. Use of small cell technology to facilitate sharing and to reduce the exclusion zones**

*NPRM (8) "... We seek comment on whether the use of small cell technology incorporating lower power levels and other distinguishing technical characteristics compared to higher power cellular architecture systems could significantly reduce the exclusion zones proposed in NTIA's Fast Track Report..."*

We believe that small cell use can significantly reduce exclusion zones to expand the area where the 3.5 GHz Band could be used for sharing with priority and general authorized access

users. Moreover, we believe that the geographic exclusion zones should also be time dependent and dynamically managed by the SAS for a more efficient use of the spectrum. The scale of time dependency would be relatively long-term (hours, days and weeks) and strictly based on the presence or absence of Federal incumbent sources such as Naval vessels within defined U.S coastal regions.

In the case of small cells, the BS transmit power can be on the order of 20dB or more below the value used in the NTIA report [1] for the WiMax technology (for example, 23dBm EIRP compared to 43dBm for WiMax in a 10 MHz channel). To estimate how the BS transmit power reduction impacts the exclusion zones, we draw from a study that compares field data from a deployment of WiMax in the 3.5 GHz band, with typical path loss models [2]. The study shows that the Friis path loss model can be viewed as an upper bound of the measurement data, and can be used to generate a conservative estimate of the path loss. We use this result and tabulate the exclusion zone distance of ship borne radar calculated from the Friis equation, assuming a 23 dBm EIRP small cell transmitter, with 3.5 GHz as the frequency, and an incumbent interference threshold as given in Table 4-5 of the NTIA in the Fast Track Report.

**Table 1 Calculated exclusion zone for small cells and Friis path loss model**

Radar Identifier	Interference Threshold (dBm)	Small Cell Exclusion zone distance (km)	NTIA Fast Track report exclusion zone distance (aggregate values, Table 5-4 NTIA)
Shipborne Radar 1	-114	49	310
Shipborne Radar 2	-101	11	45
Shipborne Radar 3	-100	9.7	53

This conservative model shows significant reduction in the exclusion zone; the use of more accurate models such as the terrain dependent model used by the NTIA in the Fast Track Report, could further reduce these exclusion zones. In addition to lowering the base station

transmit power, the use of below rooftop antennas (BRT) or a transmitter Height Above Average Terrain (HAAT) restricted to the order of 20-30m (as compared to the height of 60 m used in the NTIA Report), can also help to reduce the exclusion zone.

Furthermore, as indicated above, we believe the exclusion zone definitions should be time dependent and dynamically managed by the SAS. There are factors influencing the size of the exclusion zone other than the link budget that can be taken into account when the use of the band is managed dynamically. The exclusion zone or the Incumbent Use Zone does not necessarily have to be a permanent, constant contour around the incumbent. When the incumbent is not active or not present, there is no need for an exclusion zone in the area, and consequently there is no need to have restrictions for the Priority Access and/or GAA use in the area. There may be cases when the Incumbent use varies over time in a manner that allows different sizes or shapes for the Incumbent Use Zone. The size of the exclusion zone will also depend on the frequency and bandwidth used by the Incumbent: for co-channel operation the Zone is largest, whereas with sufficient frequency separation there may not be a need for any Protection Zone, and for adjacent channels operation the Zone size may be smaller than the maximum.

## **II. Techniques to mitigate radar interference**

*NPRM (118). “... We also believe that given a small cell deployment model, some of the assumptions made in the Fast Track Report’s analysis will not apply and would need to be revisited (e.g., small cell antenna gain, height and location (being proposed for mostly indoor use), susceptibility to low duty cycle pulsed interference, propagation modeling, and transmit power). ... The wireless broadband systems operating in the 3.5 GHz Band may need to employ interference mitigation techniques and technology that enable them to avoid or tolerate the in-band interference from the high-power radar systems. We seek comment below on proposed changes to the assumptions and technologies considered in the Fast Track Report to the modeling of exclusion zones in the 3.5 GHz band. “*

*NPRM (122). “... We seek comment and request engineering studies where high power pulsed interference signals are injected into selected wireless broadband receivers (e.g., LTE, WiMAX, 802.11) under controlled conditions to verify and analyze the interference effects to fixed or mobile stations, at varying radar signal power levels and duty cycles (various combinations of pulse width and pulse*

*repetition frequency), and other types of modulation (e.g., frequency sweeping). How effective are existing channel coding and error correction techniques in correcting for interference from pulsed radar signals, especially high duty cycle radars as those analyzed in the Fast Track Report? “*

We believe that LTE or Wi-Fi systems can be adapted to mitigate interference from high-powered radar signals, in order to operate as Priority Access or GAA users. In this response, we describe how the properties of radar systems give rise to significant spectrum opportunities that can be exploited by GAA and Priority Access users to achieve co-channel coexistence with Radar outside of the Exclusion Zone. We also describe Dynamic Spectrum Management technologies that exploit these spectrum opportunities.

Given our opinion that Priority Access devices should also be allowed to operate, on an informed basis, in regions where interference from incumbents may occur, such systems can also use flexible and resilient technologies to make use of these spectrum opportunities.

To elaborate on the abundance of these spectrum opportunities, two relevant time domain properties of typical radar systems can be considered: its mechanical rotation cycle and its duty cycle. Radars have mechanical rotation cycles that are typically on the order of 4-12 seconds per rotation with high gain antennas on the order of 30dBi. This high directivity means a Priority Access or GAA system may be free from the main beam more than 80% of the time allowing significant periods where Priority Access or GAA systems can operate on the same channel as the incumbent, outside of the exclusion zone. Even after considering side lobes, there are still continuous opportunities on the order of seconds for a Priority Access or GAA system to coexist with Radar operation to achieve significant throughput.

Furthermore, even when a Priority Access or GAA user located outside of the Exclusion Zone falls under the main beam, the Radar uses pulsed signals with a duty cycle ranging from short duty cycles on the order of 0.01% to long duty cycles on the order of 15%. For long duty cycles such as 10-20% we believe that there is enough time between pulses to send short packets

and retain QoS for time critical data to be transmitted. For example, Shipborne Radar 2 has duty cycle of 15% with an inter-pulse time of 500us as described in [1]. Comparatively we estimate that the smallest Wi-Fi packet may be sent in 90us (including an average listen time of 34us and the smallest packet size transmission of 56us). This assumes a 20MHz BW, and 802.11n data rate. Similarly, a typical Wi-Fi packet may be sent within 90us to 380us. We therefore believe that modifying Wi-Fi to operate during the inter-pulse times is possible and merits further study of its impacts to aspects such as QoS. Given that the Priority Access and the GAA users are located outside of the Exclusion Zone, and that they use low transmit power compatible with small cells, it is expected that the Priority Access and the GAA users would not interfere with the radar operation.

In the case where co-channel coexistence cannot be achieved, Dynamic Spectrum Management techniques can be used by the SAS to better assign spectrum to Priority Access or GAA users to avoid operating on the same channel as a radar burst to greatly reduce interference from the radar. The SAS could assign spectrum, or inform the Priority Access or GAA users of spectrum conditions, who may employ mitigation techniques to enable operation on that spectrum. Such a system could transition between channels in a dynamic manner for better use of the band. This approach can be combined with the co-channel coexistence methods mentioned previously.

The more information provided to the SAS by the incumbent users about the Radar characteristics, the better the quality of the interference mitigation techniques which may be developed. In the case of Priority Access users any usable information could render the spectrum more valuable, and thus Priority Access users may be willing to pay for the usage of the shared spectrum to facilitate incentives to incumbents to offset incumbent costs. We believe this is the

best way to foster a thriving shared spectrum market. We discuss this in more detail in section VII.

Military users could employ a declassification interface whereby only some specific time-space-frequency resources are made available for Priority Access and/or GAA use via the SAS. However, to protect mission critical data they may reserve unused resources (unused spectrum) in time, frequency and/or location (i.e. to act as a decoy), filter the information provided to the SAS so that no classified information is transmitted to the SAS, or issue evacuate commands to Priority Access or GAA systems when needed. The information flow would be unidirectional, from the classified spectrum manager to the SAS, as illustrated in Figure 1 of Section VII. The SAS would need to be able to support such commands.

### **III. Reduction of incumbent use zone size around existing FSS ES**

*NPRM (124) “Consistent with our proposal to create an Incumbent Access tier within the 3.5 GHz Band, we seek comment on ways to protect incumbent FSS earth stations from interference. ... With the 150 kilometer exclusion zone imposed on operations in 3650-3700 MHz as a starting point, we seek comment on ways to reduce the exclusion zone given the nature of small cells and the technical rules proposed in this Notice. Is the 150 km exclusion zone distance appropriate for mobile stations?”*

*NPRM (125) “... What is the appropriate exclusion zone distance for future 3.5 GHz Band users given our proposal to allow only low-power small cell use in the band? What other mitigation techniques, such as spectrum sensing, could be employed to reduce or eliminate the size of these Incumbent Use Zones?”*

*NPRM (126) “We also seek comment on ways to arrive at other reasonable technical protections and appropriate system architectures for the 3.5 GHz Band. Regarding the incumbent FSS earth stations, what are the potential interference scenarios we must consider? How could they be mitigated?”*

In our view the best way to protect the FSS earth stations is to have a sufficient exclusion zone around each station, in which the portions of the band that are used by the FSS earth station are not used by other systems. This can be ensured by utilization of geo-location technologies, and Citizens Broadband Service (CBS) operation under the control of the SAS, as follows.

It is assumed that all FSS stations operating in-band would register with the SAS database, and provide geo-location information (latitude, longitude and altitude coordinates) and nominal antenna pointing orientation (boresight, azimuth and elevation angles) to the SAS database. Furthermore, due to FSS stations solely servicing GeoStationary Orbiting (GSO) satellites and the very small shifts with normal FSS station keeping operations, real-time re-pointing updates are not anticipated. Existing FSS stations servicing satellites in new GSO orbital positions could be handled as a required update to an existing FSS station registration.

Spectrum sensing cannot be used to detect nearby FSS earth stations, as it is in practice not possible to sense the extremely low level satellite downlink signals with the relatively low gain antennas to be used in the foreseen equipment of the proposed CBS. However, as the FSS information described above would be registered within the SAS database, the SAS can ensure that the CBS systems will respect the exclusion zones.

In our view the 150 km exclusion zone around the FSS earth station seems much too large to be used in this context, especially when this exclusion zone is based on sharing studies that used high power WiMAX devices (43 dBm peak transmit power in a 10 MHz band, [1]) as an example of the mobile radio technology. With the intention to utilize small cells, we believe the required exclusion zone can be reduced significantly; further studies are required to determine the exclusion zone using typical technical parameters of a small cell LTE or Wi-Fi deployment.

Additionally, when considering the operating characteristics of specific FSS stations (e.g. geo-location information, antenna pointing orientation and elevation angle), three-dimensional spatial maximum emission contours can be calculated and referenced to the registered position of

the FSS station in the SAS database. Such contours would be unique to each FSS ground station and its operating characteristics, and would allow tighter asymmetric exclusion zones.

In addition, we believe that the employment of SAS and advanced mitigation techniques can further reduce the size of the exclusion zone from this baseline figure. If technical characteristics both from the FSS earth stations and the CBS technologies to be deployed can be made available to the SAS, it can calculate the size of the required exclusion zone more precisely. It is also possible to have the actual terrain data available, which further improves the estimation accuracy of the size of the zone. Economic incentives for the incumbent may also facilitate in the long term, a more efficient use of the spectrum by the FSS systems.

We would like to emphasize that the exclusion zone should not be considered as a constant contour around the FSS earth station, into which the CBS systems can never operate within. In reality the exclusion zone could be different for co-channel operation, for adjacent channel operation and for frequencies deviating more from the frequencies used by the FSS, as we pointed out in Section I. The better the selectivity of the FSS receiver, the less there are restrictions for CBS systems using frequencies outside of those used by the FSS receiver. Good input filtering and shielding can allow operation of CBS even down to close distance from a FSS earth station when the CBS system uses other frequencies than the FSS station. The SAS should be aware of the frequencies used by the FSS, and can take note of the foreseen changes so that the CBS systems can adapt accordingly.

Another potential interference scenario that can be considered is when the high power FSS ground station radiates from its transmit antenna sidelobes or backlobes, and interferes with the Priority Access / GAA tier users. A mechanism that could be looked at in this context would be to have CBS devices conform to requirements for adjacent channel rejection performance

(similar to the recommendations in the PCAST report). Alternatively, the CBS receiver capability could be included in the SAS registration procedure, thus enabling the SAS to perform frequency assignments based on the CBS receiver capability.

All in all, assuming the SAS is cognizant of the previously specified technical characteristics of registered FSS earth stations and CBS small cell BS and UE devices that are to share the 3.5 GHz band, then we believe that the size of the exclusion zone can be made significantly smaller than the baseline value.

We also support the proposed moratorium of the application of new FSS stations in the band 3600-3650 MHz.

#### **IV. Priority Access tier systems and technologies**

*NPRM (9). “... We seek comment on who these eligible users should be and suggest that they could include hospitals, utilities, state and local governments, and/or other users with a distinct need for reliable, prioritized access to broadband spectrum at specific, localized facilities. “... ”*

*NPRM (70). “... Priority Access operations would be permitted only in geographic areas where Citizens Broadband operations would not interfere with incumbent operations and, because they would have a quality-of-service expectation, where no interference from incumbent operations would be reasonably anticipated (Priority Use Zones)....”*

*NPRM (71). “We seek comment on whether Priority Access operations should be allowed in the 3.5 GHz Band. Commenters should consider the following questions: Should a Priority Access tier be implemented and, if so, is this the appropriate scope? Should critical safety-of-life applications be permitted in this tier? Would Priority Access users be able to achieve a meaningful level of service given the restrictions we have proposed? Would Incumbent Access tier users be sufficiently protected from harmful interference? How would the SAS dynamically manage interaction between the Priority Access tier and other tiers? Should Priority Access devices be explicitly limited to indoor operations or would higher power levels and expanded, outdoor operations be appropriate? Commenters are encouraged to provide detailed comments and proposals, including alternatives to the proposals in this Notice and to fully address implementation details of the dynamic database as well as the technical licensing and regulatory ramifications of the proposal in this Notice with respect to Priority Access users.”*

InterDigital agrees with the creation of a Priority Access Tier in the 3.5GHz band as a means to provide an alternative to or to complement the traditional dedicated spectrum for certain specific users with strict quality-of-service needs. While we agree that such users could

include certain mission critical services such as hospitals, utilities, and state and local governments, we also believe that commercial network operators such as mobile network operators, Wi-Fi aggregators, and enterprise networks should be included as eligible users of the Priority Access Tier. As quality of service is also important from the point of view of commercial network operators, and demand for commercial broadband capacity is growing significantly, commercial network operators would benefit significantly from the use of Priority Access Tier spectrum in the 3.5GHz band. In addition, the use of small cells in 3.5GHz being proposed in this NPRM is very much in line with the current work in 3GPP that is focused on small cells to further improve the efficiency of operator spectrum and offload of congested macro cell traffic. It can be expected that such small cells will be deployed in the 3.5 GHz band identified for IMT in Europe and in many Asian countries [5]. Therefore, allowing the use of Priority Access Tier by mobile network operators would increase the size of the market and economies of scale for products which fulfill the technical requirements of this band. This would also make such products in the 3.5 GHz band more easily accessible for specialized usage applications as being proposed by the NPRM for the Priority Access Tier.

InterDigital also believes that allowing the use of the Priority Access Tier in 3.5GHz spectrum by mobile network operators would bring further benefits by exploiting synergies between specialized uses (such as public safety) and commercial uses. Such synergies are currently being investigated in Europe as part of the EC mandate on Cognitive Radio Systems. Also, 3GPP has started to look at LTE for public safety systems [6][7][8], and it is expected that most public safety systems will move to the use of LTE in the very near term. We believe that creating Priority Access Tier that is available to both specialized uses (such as public safety systems) and commercial network operators will further encourage new collaborative models

that will benefit both the specialized users and the commercial network operators. For instance, specialized users/utilities could be provided with network infrastructure built or maintained by a commercial network operator, while the network operator would benefit from the use of new spectrum in exchange.

InterDigital agrees that creating a Priority Use Zone whereby a system in the Priority Access Tier would be protected from interference from Incumbent access tier systems would ensure that Priority Access Tier systems can operate without harmful interference and provide quality of service. However, we believe that such Priority Use Zones would not need to be fixed zones which are statically determined by geography only, but could be determined through appropriate database management by the SAS, based on the usage of the Incumbent Systems at any given time. In other words, the areas to which Priority Access Tier Systems would be restricted could change depending on the usage of spectrum by Incumbent Access systems at any given time, and would be controlled by the SAS. While a fixed Priority Use Zone may be beneficial for critical safety-of-life applications, where 100% guaranteed access to spectrum at specified locations at any time is required, use of Priority Access Tier by commercial operators or other specialized users in areas where spectrum may not always be available, would still be valuable as quality of service could be provided for specific periods of time (as managed by the SAS). Availability of spectrum for certain, predictable periods of time due to changes in spectrum usage by the incumbent systems, would be beneficial in providing hot-spot bandwidth during periods of congestion or special events, and increase the overall availability of bandwidth.

InterDigital also believes that the priority access tier should not be limited only to indoor applications but should also be extended to outdoor operations also. We believe that the protection of the incumbent access tier in the 3.5GHz should depend more on factors such as

antenna height above sea level and actual power, rather than indoor or outdoor usage, since an indoor application at the top of a high-rise may be more detrimental than a low-power outdoor application at ground-level and surrounded by buildings. We also believe that limiting Priority Access devices to indoor use only would severely limit the number of applications that could make use of the 3.5GHz spectrum, thus reducing the chances of widespread adoption of this band for small cells.

*NPRM (74). “Band Plan. We propose to allow Priority Access services across one-half of the 3.5 GHz Band (50 megahertz). We believe that this approach would provide adequate capacity for Priority Access users while ensuring that GAA users may access the remainder of the spectrum at any given location. We seek comment on this approach, including whether dividing the 3.5 GHz Band in this manner would serve the public interest. We seek comment on the specific portion of the band that should be reserved for Priority Access uses. We also seek comment on whether the specific frequencies available for Priority Access use should be set by rule to be consistent on a nationwide basis or should be set dynamically in the SAS on a location-by-location basis.”*

InterDigital believes that the amount of spectrum assigned to the Priority Access Tier should not be fixed or static, but rather determined dynamically by the SAS based on the spectrum needs in any given area. We also believe that the specific frequencies available for each system should also be set dynamically by the SAS both on a location-by-location basis, as well as based on the current needs of the spectrum at that location at a given time. For instance, in areas where there is a greater need for Priority Access Tier spectrum, the SAS could assign more spectrum for this Tier and reduce the amount of GAA spectrum accordingly. Conversely, and consistently with what is proposed in the NPRM, when there is less need for Priority Access Tier spectrum in a given area or at a given time, the SAS could allow the use of more spectrum by the GAA systems. In addition, the amount of spectrum assigned to each Tier could change over time as more or less users of each Tier request access to the spectrum. To ensure that GAA users may access the spectrum, the amount assigned for Priority Access use should be upper

bounded by a certain limit. Further studies are needed to determine an upper limit for the amount of spectrum assigned to the Priority Access Tier.

While a more static approach which allows Priority Access service across one-half of the 3.5GHz band would simplify the provisioning of QoS for Priority Access systems, implementing a band plan that does not statically identify the portions of the spectrum that are reserved for Priority Access users and GAA users would significantly increase the efficiency of spectrum usage. In this case, spectrum could be made available by the SAS at a given time, frequency, and location to the users which need the band, thus resulting in an overall increase in the number of users. It also provides for a more flexible management of spectrum by the SAS, which allows better exploitation of pockets of available spectrum which are likely to exist as the number of users increases. We further believe that development of intelligent spectrum assignment algorithms in the SAS (as further discussed in section VII) would allow the provisioning of QoS and adequate capacity of spectrum for Priority Access systems despite the use of a dynamic band planning. Such algorithms would necessarily need to give priority to the spectrum request from the Priority Access usage over the requests from the GAA usage, while ensuring that the amount of spectrum assigned for Priority Access use is upper bounded to a reasonable value.

In addition to allowing more efficient spectrum usage, a dynamic band plan will promote the development of systems and equipment that are capable of using the entire 3.5GHz band, thus contributing to economies of scale and facilitating the access to these devices and systems by any type of user or operator which needs to utilize the 3.5GHz band in the future.

*NPRM (77) “In addition to the proposal set forth above for the 3.5 GHz Band, we seek comment on the potential inclusion of the 3650-3700 MHz band into the proposed regulatory regime. The 3650-3700 MHz band is currently licensed on a “licensed light” basis whereby prospective operators may register for ten-year, non-exclusive, nationwide license to operate facilities in the band. The Commission adopted this innovative licensing model to encourage multiple entrants and promote rapid*

*deployment of wireless broadband services to rural and underserved areas of the country. Currently there are 2,117 licensees with more than 25,000 registered sites throughout the United States. These licensees are providing a variety of important services to utility companies, public safety entities, businesses, and consumers”*

InterDigital also supports the proposal to include the 3650-3700 MHz band in the regulatory regime proposed in this NPRM. If most of the licensed operators in this band are in rural and underserved areas of the country, then they are in geographic regions not likely to be impacted by small cell deployment, as the small cell market is greatest in urban and densely populated suburban areas. This would facilitate the inclusion of the 3650-3700 MHz band into the proposed regulatory regime. However, in areas where interference may occur between devices currently operating in the “lightly licensed” regime and those which will eventually operate in the 3550-3650 MHz band, the interference would be mitigated by use of devices with reliable sensing technology, and by the central management of the SAS. It is assumed that all Priority Access and GAA users of the extended band would be required to register with the SAS, thus ensuring a consistent procedure across the expanded band, as well as a reliable interference management enabled by the SAS.

## **V. Technologies to enable efficient GAA use of the 3.5 GHz band**

*NPRM (10). “... We seek comment on what technologies could be used to enable effective GAA use of the 3.5 GHz Band...”*

We believe that as long as GAA users are required to register with the SAS, to comply with all applicable technical requirements, and with the regulations to ensure that they don’t create harmful interference to IA and Priority Access users, there should not be any restriction on what types of users could be in this category. Moreover, we believe that both Wi-Fi and LTE are technologies that can enable effective GAA use of the 3.5 GHz band. Both technologies can evolve to fulfill the technical requirements for the CBS and to also include mitigation techniques

that facilitate operation in locations where interference from the Incumbent may occur. The mechanism of registration with the SAS ensures that the GAA systems do not create harmful interference to the Incumbent Access and Priority Access users, and can also be used for coordinated coexistence of LTE and Wi-Fi as GAA users. Additionally, non-coordinated coexistence between GAA LTE and Wi-Fi systems is also possible, as was shown in [3] and [4]. For example, using silent gaps in the LTE transmission provides opportunities for GAA Wi-Fi users to access the spectrum. More specifically, Wi-Fi users employing CSMA would sense the channel as available during the silent gaps in the LTE transmission (also referred to as the coexistence gaps), and access the channel. Conversely, Wi-Fi users would detect the channel as busy during the LTE transmission, and would not attempt to use the channel. Thus, as explained in detail in [4], coexistence gaps appear to be a feasible approach to non-coordinated coexistence between LTE and Wi-Fi systems operating as GAA users, which can help make effective GAA use of the band. Further studies are needed to ensure the fairness of the non-coordinated coexistence approaches. Sensing may also be used to enhance both the coordinated and non-coordinated mechanisms for GAA coexistence in this band. Additionally, as explained in Section VII, smart radio resource management (RRM) algorithms running at the SAS, together with non-contiguous aggregation, channel management and sensing for interference management would be key factors in ensuring effective use of the 3.5 GHz band.

## **VI. Use of license-by-rule**

*NPRM (11). “Under our main proposal, users in the Priority Access and GAA tiers would be licensed by rule as Citizens Broadband Service users under Part 95 of the Commission’s rules. A license-by-rule approach would provide individuals, organizations, and service providers with “automatic” authorization to deploy small cell systems, in much the same way that our Part 15 unlicensed rules have allowed widespread deployment of Wi-Fi access points....”*

InterDigital agrees with the use of the license-by-rule approach for both the Priority Access and GAA tiers. We believe that the license-by-rule approach helps in implementing a more dynamic use of spectrum than traditional licensing or temporary licensing, thus increasing the spectrum availability at a given time. It will also enable a larger number of users to have access to the band, as this access can be made without the costs of a traditional license.

The license-by-rule approach, with the rules specifying registration with the database, and the other techniques under consideration, results in a more controlled access to the spectrum when compared to the unlicensed usage of Part 15. This will be beneficial in managing not only the quality of service requirements of the Priority Access users, but also managing the spectrum for GAA users and avoiding harmful interference to incumbent users.

InterDigital also believes that a uniform approach to licensing for both tiers will allow for a more flexible determination of the band assignments by the SAS for the two tiers, which is also desirable to achieve overall spectral usage efficiency for the 3.5GHz band. Although a license-by-rule approach allows for term-less licensing, we believe that as the automatic authorizations proposed by this approach will be controlled by the SAS, the time related aspects of the assignment process can be covered sufficiently. Such control will only allow access for certain users based on frequency, time, and location in order to protect the incumbent users and other Priority Access Tier users.

One open issue seems to be how eligible Priority Access users are identified and which users are allowed access to the band at a given frequency, time and location over others. An additional step may be needed where the eligible Priority Access users are registered with the SAS, and by doing so get access rights to the SAS which can then assign spectrum for them. Spectrum assignment decisions would need to be made according to some predetermined rules

that are applied by the SAS. Such rules would depend on policies determined by the regulator. The use of registration in connection with a term-less licensing by rule and actual authorizations made by the SAS would in our view offer a new flexible licensing scheme suitable for network operators.

In addition, as the number of Priority Access users willing to use spectrum at a given time or location may exceed the actual available spectrum, we believe it will be necessary to institute a payment mechanism for the usage of Priority Access spectrum by non-critical users. Payments made by such users will address the issue of excess demand that will be likely in certain areas and also ensure more efficient use of Priority Access spectrum. Part of the funds collected through this mechanism could be used to offset the regulatory costs, as well as SAS maintenance costs, while the remaining funds could be used as a payment to the incumbent systems which make the spectrum available, thus providing them with an incentive to provide access to their spectrum where and when it is unused. However, regulations and rules need to be put in place that do not encourage incumbents to simply cease operation in the spectrum and collect fees from Priority Access users and others. At the same time, it is important to enable fair access to spectrum, for example by GAA (who would not be expected to have to pay to use the spectrum), and by non-critical Priority Access users. We are of the opinion that if such an incentive mechanism, in conjunction with well defined policies from the regulator, are part of the authorization decisions made by the SAS, the license-by-rule model will provide better usage of the 3.5GHz band and create new opportunities for the eligible Priority Access users.

## **VII. Spectrum Access System (SAS)**

*NPRM (58). “... below we seek detailed comment on the design of the SAS, including appropriate data security protection for sensitive federal information...”.*

NPRM (65). “... Incumbent protection would be enforced by the SAS and would include strict geographic limitations on Citizens Broadband Service use. We seek comment on this proposal generally, including proposed implementation details of the SAS, and on the specific protections for federal and commercial incumbents set forth below.”

NPRM (71). “... How would the SAS dynamically manage interaction between the Priority Access tier and other tiers?...”.

NPRM (95). “... We seek comment on the use of a dynamic spectrum access database, the SAS, to manage access and mitigate interference between all users in the 3.5 GHz Band. We also seek comment on what type of information must be included in the database and what technologies and techniques could be incorporated to protect classified and sensitive but unclassified federal data that is not publically releasable.”

InterDigital shares the Commission’s view that database and dynamic spectrum management technologies can be used to manage access and to prevent interference between small cell users and incumbents. We believe that the SAS will be a key component of the 3.5 GHz shared spectrum band. The SAS interfaces with classified and non-classified spectrum management entities, as shown in the example below.

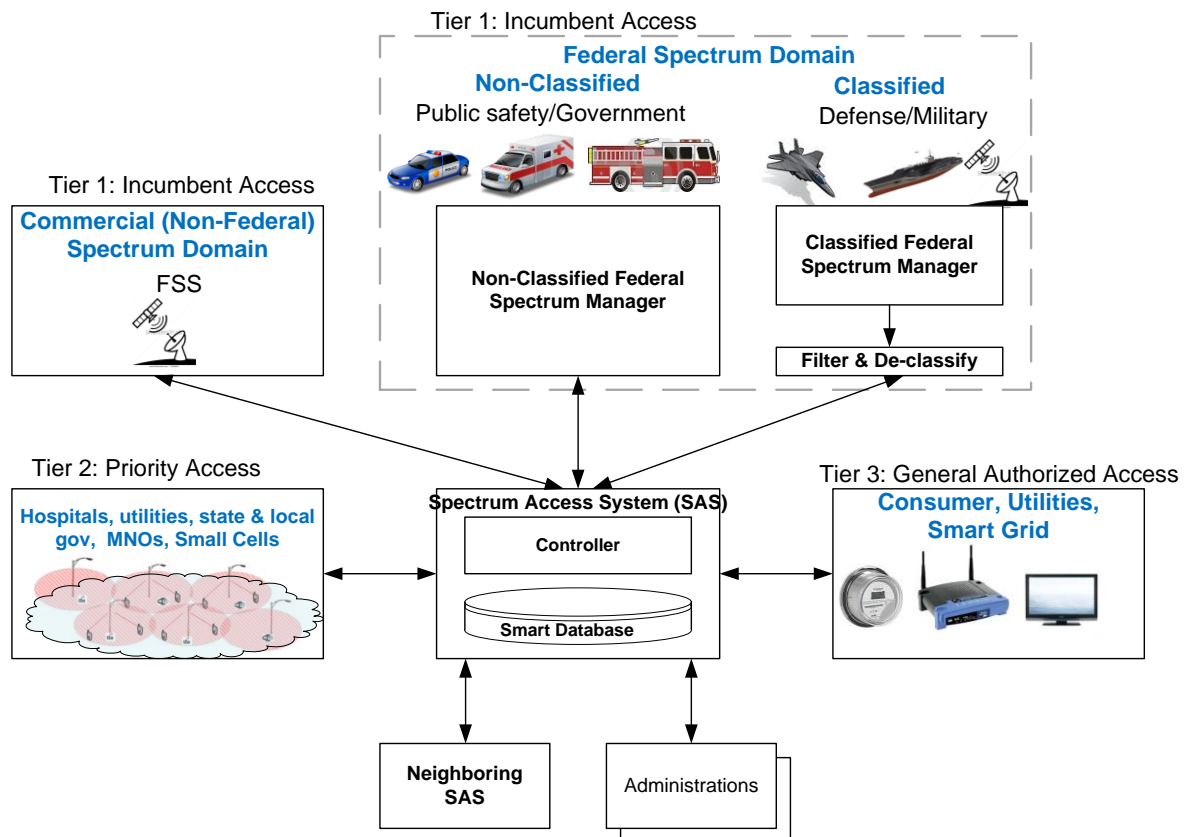


Figure 1 High level diagram of an SAS system

We believe that the classified Federal spectrum manager will need to communicate with the SAS in a secure way, by filtering information about classified spectrum usage. This can be achieved through sending a limited amount of information about the spectrum available only, or by performing a subtask of the overall work done by the SAS (which would otherwise require sensitive information about the spectrum usage and physical characteristics of the classified spectrum). Some properties of the filtered spectrum information could include: the absence of any PHY layer characteristics of the incumbent systems with which sharing will be done (e.g. modulation scheme, spectral masks, etc), the absence of detailed geolocation information (such as location of stations, range, etc), as well as the ability to conceal exact time, location and frequency of spectrum usage in a band by not making all available spectrum usable by the SAS. Additionally, the classified Federal spectrum manager could have additional flexibility to refuse certain spectrum usage based on the identity of the Priority Access / GAA user proposed for usage, as well as the ability to modify or set certain spectrum usage parameters initially proposed by the SAS.

In addition to a regulatory framework that would define certain policies on how the SAS may assign spectrum, we believe that other keys to the success of the 3-tier spectrum sharing approach are the incorporation of an incentive system (to encourage the incumbents to share their spectrum, when and where it is not fully used), and a dynamic bidding mechanism (that would encourage the Priority Access and GAA system to efficiently use the spectrum). As a result, the protocols implemented in the SAS would need to address the aspects of supply, demand, as well as incentive and pricing.

A possible way for the SAS to dynamically manage the interaction between the Priority Access tier and other tiers is through the joint use of signaling to the access users to vacate the

spectrum, and of a “time-to-live” (TTL) mechanism (as defined in the PCAST report [9]). When the SAS assigns spectrum to Priority Access and/or GAA users, it would also assign a validity time (or “time-to-live”) for which the spectrum assignment is valid. The TTL may be larger for Priority Access users, and smaller for GAA users. Upon the expiration of the TTL, the Priority Access/GAA users would need to signal to the SAS the request for renewal. At renewal time, the SAS may deny renew requests from GAA users to ensure incumbent protection, as well as to maintain a level of quality of service for the Priority Access users.

In order for the SAS to maintain a guaranteed QoS for the Priority Access users, the SAS would need to collect spectrum usage metrics from the Priority Access users. These metrics would be used by the SAS to determine whether to accept or deny TTL renewal requests, as well as new access requests from users. Further studies are needed to define the specific metrics to be reported, the reporting intervals and corresponding algorithms.

Additionally, when an Incumbent user needs to access the spectrum immediately, for example in an emergency situation involving a mission-critical incumbent system, it would signal the request to the SAS, which would then signal spectrum release commands to the affected Priority Access and GAA users to vacate the spectrum.

*NPRM (58). “... below we seek detailed comment on ... and whether the existing TVWS database model could be modified to accommodate the 3.5 GHz Band....”.*

*NPRM (97). “We seek comment generally on the SAS design and specifications necessary to ensure that access is accurately managed and interference is successfully mitigated. Building upon the Commission’s experience in the TVWS context, we seek comment on the key elements of a SAS, including the architecture and number of databases or systems, the creation and management of the SAS, the parameters necessary for an effective SAS, and security measures to ensure the SAS and transmissions to and from the SAS are secure. Alternatively, consistent with PCAST’s recommendation, we seek comment on whether the existing TVWS databases could be modified to include parameters necessary for facilitating coordination between and among 3.5 GHz Band users.”*

The SAS can be seen as a sophisticated evolution from the rather simple geo-location databases currently being developed and deployed for the operation of White Space Devices in the UHF broadcast band in the US. The TVWS geo-location database system implements a simpler 2 Tier system where the main protected incumbent users are terrestrial broadcasting and PMSE. In contrast, the SAS would need to implement a 3-tier hierarchical system that needs to ensure incumbent protection, perform dynamic frequency assignments to Priority Access and GAA users, collect the spectrum usage metrics from the Priority Access users, manage the TTL of the non-incumbent systems, as well as (possibly) manage the incentive and bidding system. The information that the SAS database may need to store for effective spectrum management, would include (but is not limited to): geo-location information for incumbent systems (filtered as explained above in case of sensitive federal systems), time, frequency and bandwidths of the systems accessing the spectrum, transmit powers and spectral masks, radio access technologies being used, receiver sensitivity requirements (where needed or applicable for coexistence purposes), and so on.

*NPRM (98). “Administration. We seek comment on whether the Commission, a commercial entity, or another federal entity should create and manage the SAS. PCAST envisions some level of federal involvement due to the need to access non-classified data and filtered classified data to facilitate spectrum sharing between federal and non-federal users.”*

In our view the preferred solution would be to allow commercial entities to develop and operate the SAS, as this would encourage increased competition, foster innovation, and potentially lower the costs of development and deployment of the SAS, as well as the cost of using the services of the SAS. We agree that some federal involvement would be needed, and there would also be a role for the administration related to the supervision and definition of relevant policies. In case economic incentives for incumbents are employed, the costs of the

development and operation could be covered. Such an approach would not create a financial burden for the federal entities or for the administration.

*NPRM (99). “We also seek comment on whether, if we opt to allow commercial entities to create and manage the database or databases, we should authorize multiple database administrators.”*

We believe that support of multiple database administrators encourages competition, with positive benefits to innovation and costs.

*NPRM (100). “Finally, we seek comment on enforcement mechanisms. What would occur if a device operated outside of the parameters authorized by the SAS? Can safeguards be built in to Citizens Broadband devices and the SAS to power down any device that, due to human intervention or technical malfunction, operates in a manner inconsistent with the device’s authorization? Can the devices be made effectively “tamper resistant”?”*

The threat posed by a Citizens Broadband device operating outside of the parameters authorized by the SAS is severe, and is made more so by the fact that interfering devices could be extremely difficult to identify and prevent. The potential exists for end-user modification of devices in ways that could cause significant harmful interference to critical communications services.

Behavior of such a device may be controlled by the policy applicable to that device. Such policy may be enforced either from the network or locally. Either way, ***trustworthy and assured policy execution*** will require a ***trusted device platform***. Remote shut down of a Citizens Broadband device may be initiated by a network element. There is a necessity to have an appropriate legal framework behind such a drastic measure (e.g., forced shut down of a device will make it impossible to make an emergency call, etc.) from a technical point of view, the event detection has to be communicated from a device to the network for making a decision based on the pre-defined policy and the received event report. It is important to understand that all elements of this reporting chain have to be trusted (i.e., the endpoints consisting of the device

and the network element, as well as the communication channel). The policy decision reached at the network element has to be communicated back to the device, forcing it to perform the unscheduled shutdown. Same as with event reporting, all elements of this action chain have to be trusted (i.e., the endpoints consisting of the device and the network element, as well as the communication channel.)

When a device is trusted and protected against tampering, it becomes possible to store and execute downloaded policies in the protected area of the device, effectively collapsing policy enforcement, policy application, and the communication channel into the protected area of the device. Such collapsed architecture provides an additional benefit of relaxing availability requirements for the network policy control.

The devices can be made to support both, tamper evidence and tamper resistance, capabilities. Tamper evidence capabilities may be needed to support tamper resistance and may include purely physical tamper evidence elements (e.g., self-destructing and one-time use mounting screws, etc.) or alarm notification systems (e.g., “case open” contact switches, etc). Logical tampering may be detected by light footprint Intrusion Detection Systems (IDS). Overall, tamper resistance may be passive or active. Examples of passive tamper resistance capabilities include such physical protection as inverse positioning of IC elements or covering of PCB elements with epoxy resin. Active tamper resistance would require a tamper alarm to be triggered (e.g., brute force shared secret attack trigger in modern UICC cards, triggering UICC card lock down.)

In recent years, use of trusted computing technologies, which provide assurances and quantifiable evidence of the functionality of a device similar to a hardware implementation or “hard-wired” device have been developed for practical application to consumer products. These

technologies exist in all laptops today in the form of TPM chips and in rudimentary form in many cellular radios as proprietary security mechanisms. Indeed the Global Platform has specified architecture requirements for secure environments and applications programming interfaces for such elements and is promoting the use of secure environments for mobile platforms. Additionally, the Trusted Computing Group is working on creating trust security solutions for mobile platforms, which leverage secure environments as well as a hardware anchored root of trust to ensure trustworthy platform bring up and configuration of the platform and secure environment. Many silicon manufacturers are adopting such requirements to standardize and promote adoption of such technologies in mobile devices to ensure that software may be run in a secure, tamper proof manner.

InterDigital has been developing technologies which leverage the use of trusted computing technologies in the form of secure environments and root of trust to deliver an overall tightly controlled system level trust security solution. The work has been on the creation of a practical approach to trust security for mobile systems and which separates access control decisions from remediation in the network by balancing trust processing between the mobile device and the network [10,11].

Such an approach would:

1. Certify the Citizens Broadband devices for their security architecture and use of trusted computing technologies such as secure elements anchored through a hardware enforced root of trust.
2. Provide for the remote assessment of the secure state of a Citizens Broadband device, which essentially enables the software based functionality to be “hard-wired”.

3. Enable the remote provisioning, management and update of SAS policies, which may be executed on the Citizens Broadband devices.
4. Use the trusted computing base of the Citizens Broadband device to prevent execution of radio functionality outside of the authorized and provisioned policies.

InterDigital's view is that by promoting the adoption of these technologies, configurable but protected usage policies, may be executed on Citizens Broadband devices to enable the safe and legally authorized use of Citizens Broadband devices.

## **Conclusion**

InterDigital welcomes the Commission's proposal to create a new Citizens Broadband Service in the 3.5 GHz Band and supports the use of spectrum sharing and small cells in this band. As indicated in our comments, we believe that the use of small cells helps reduce the exclusion zones proposed in the NTIA Fast Track Report, and also reduce the Incumbent Use zone around existing FSS earth stations. Additionally, we proposed mechanisms for the CBS devices to mitigate radar interference while operating outside of the exclusion zone. We also believe that the Priority Access Tier should be opened to commercial network operators, and in Section IV of this document we provided the reasoning behind this proposal. We provided our view regarding the use of the license-by-rule for Priority Access and GAA tier users. In the context of SAS design aspects to manage the use of the 3.5 GHz band, we expressed our opinion that economic incentives for the incumbent, in conjunction with a bidding mechanism, are a key factor that can contribute to the success of the proposed spectrum sharing model, and lastly we described current and future technologies to enable the safe and legally authorized use of the service.

InterDigital appreciates the Commission's consideration of its comments and welcomes any questions concerning its technologies.

Respectfully submitted,

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